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High-contrast Imaging Study on the Candidate Companions Around the Star AH Lep

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AH Lep (R.A.$_{J2000}$ = 05 34 09.16, decl.$_{J2000}$ = −15 17 03.18) is a young, nearby, solar-type star (G2V). *Gaia* DR2 and BANYAN Sigma provide a 99.9% probability of the star belonging to the Columba moving group (Zuckerman et al. 2011), yielding an estimated age of 42^{+6}_{-4} Myr (Bell et al. 2015). It has a parallax of p = 17.26 mas, corresponding to a distance of

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d = 57.9 pc (Gaia Collaboration et al. 2018). The star has been reported to have variable photospheric and X-ray emission (e.g., Burleigh et al. 1998; Cutispoto et al. 2003).

AH Lep was first observed in high-contrast imaging in the H-band as part of the SEEDS survey by Brandt et al. (2014). They used Angular Differential Imaging (ADI, Marois et al. 2006) to search for candidate companions (CCs) around the star and they did not report any CCs within 7.″5 (~400 au).

In this research note, we report AH Lep high-contrast imaging observations obtained using Very Large Telescope/SPHERE (Spectro-Polarimetric High-contrast Exoplanet REsearch, Beuzit et al. 2019) installed at ESO Paranal Observatory, Chile, within the SpHere INfrared survey for Exoplanets (SHINE, Chauvin et al. 2017). Observations took place on 2018 January 28th, using the IRDIFS mode, which simultaneously allows dual band imaging with the IRDIS camera (Dohlen et al. 2008; Vigan et al. 2010) in $H2/H3$ filters (1.59 μm and 1.66 μm, respectively), and Integral Field Spectroscopy (IFS, Claudi et al. 2008) in the $Y-J$ bands (0.95–1.32 μm, $R\sim 50$). The data, taken in pupil tracking mode, were reduced in the standard way, making use of the SPHERE Data Center pipeline (Delorme et al. 2017).

For the data analysis, we used the ANgular Differential OptiMal Exoplanet Detection Algorithm (ANDROMEDA, Cantalloube et al. 2015), which utilizes an inverse problem approach to search for CCs. Two candidates were found at an angular separation of 421.0 ± 3.4 mas and 769.8 ± 3.5 mas, which correspond to a projected separation of 24.3 ± 0.1 au and 44.5 ± 0.2 au, respectively (see Figure 1, left), and with $H2$ magnitudes being 12.2 mag and 12.6 mag fainter than AH Lep, corresponding to a contrast of $12.70\times 10^{-6}\pm 1.54\times 10^{-6}$ and $8.62\times 10^{-6}\pm 1.14\times 10^{-6}$, respectively.

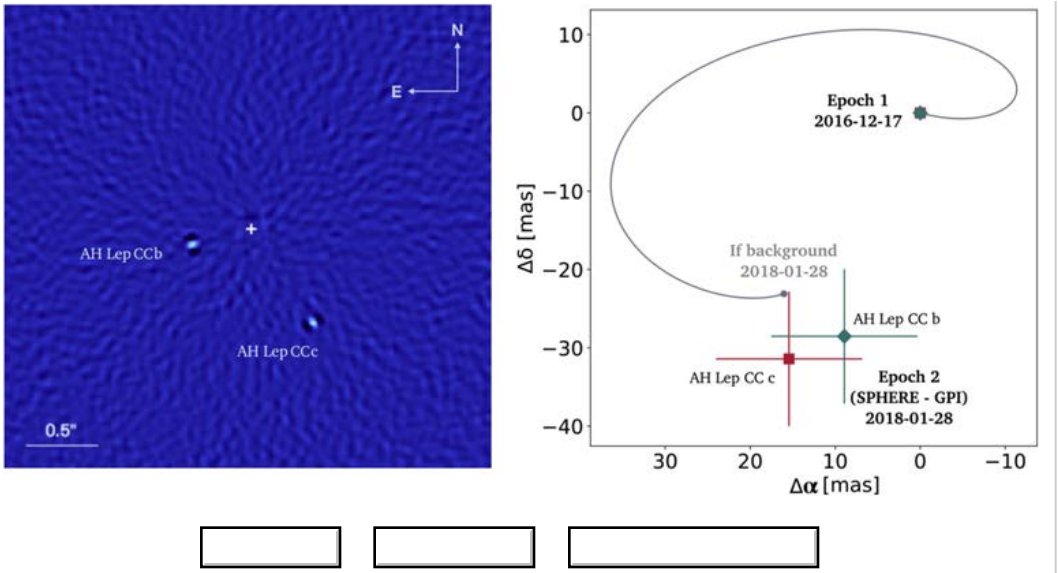

Figure 1. Left: SPHERE/IRDIS ANDROMEDA image of AH Lep obtained in *H*2. The white cross indicates the position of the star. Right: relative astrometry of the CCs of AH Lep. The markers show the measurements of the relative positions of the CCs, at both the initial epoch, and further in time at the SPHERE-GPI epoch. The gray line traces the path a stationary background object would have followed relative to AH Lep between the two epochs.

In order to test if these two companions are bound, we performed an astrometric analysis combining the SPHERE data with archival *H*-band data from the Gemini Planet Imager (GPI, Macintosh et al. 2014) at the Gemini South telescope on Cerro Pachon, Chile, obtained on 2016 December 17th. The data were reduced with the public pipeline (Perrin et al. 2014, 2016), and afterwards we applied ANDROMEDA to search for companions. Two CCs were found in this data set, and their astrophysical parameters are consistent with the ones found from the SPHERE data. Our results of the astrometric analysis are shown in Figure 1, right, where we plot the relative astrometry between SPHERE and GPI. We also indicate the combined uncertainties of SPHERE+GPI data, which are dominated by the systematic uncertainty between the SPHERE and GPI astrometry, and not by the measurement procedure. We found that the CCs are most likely background sources as they appear to follow the stationary background track. The astrometric analysis was calibrated following the procedures in

Maire et al. (2016) for the SPHERE data, and following Konopacky et al. (2014) for the GPI data.

Additionally, we extracted the spectra of the two point sources from the SPHERE/IFS data, where we found no significant evidence of methane (CH_4) absorption, suggesting that they do not belong to the T dwarf class. This absence may be due to several reasons, e.g., clouds in their atmospheres. A more detailed analysis of the spectra of the point sources might help to clarify their nature, however, this lies beyond the scope of this research note and will be left for future work.

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